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ABSTRACTS

BASIC SCIENCE/SAFETY

1\*

MULTIPHOTON EXCITATION OF ENDOGENOUS PHOTOACTIVE COMPOUNDS AND EXOGENOUS PHOTODYNAMIC AGENTS *IN VIVO*. C. Dees, WG Fisher, MG Petersen, T. Scott, and EA Wachtel. Photogen, Inc. Knoxville, Tennessee 37931

Simultaneous multiphoton excitation (MPE) of photoreactive compounds offers many advantages over conventional single-photon excitation (SPE). The purpose of this study was to demonstrate MPE *in vivo* by excitation of endogenous photoactive compounds associated with melanogenesis and by excitation of exogenous photodynamic agents. Many melanogenic compounds are phototoxic after photoexcitation. Excitation of such melanogenic products should induce killing of melanoma cells. Nude mice (Cr:NCr-*nu*BR) were subcutaneously injected with approximately  $10^4$  M3 mouse carcinoma cells. The resultant tumors were illuminated with 730 nm light generated by a Ti:S laser (200 fs pulses at 76 MHz). Treatment of subcutaneous melanomas was found to reduce tumors 100% when the tumor depth was 2–3 mm and exhibited no recurrence. Deeper tumors exhibited a higher recurrence rate – this should be corrected by altering procedures so that greater depth of light penetration into the tumor is achieved. Hairless (Cr:SKH1-*hr*BR) mice were treated with porfimer sodium (Photofrin™) and the liver illuminated *transcutaneously* with the Ti:S laser at 730nm. SPE in mouse liver was produced using continuous wave excitation at 630nm. Photodynamic effect was confirmed by standard gross and histopathologic procedures. Livers illuminated using MPE showed lesions characteristic of applied PDT agents. MPE produced sharp margins and a lack of hemorrhage around the target area. No collateral damage to organs or line of flight damage to the skin or body wall has been observed. In contrast SPE produces

hemorrhage and a large zone of collateral damage to liver and line of flight damage to the skin and body wall. When compared with SPE, MPE was found to be safer and more effective in performing photodynamic therapy

2

LASER EXCITATION OF LIPOSOMES WITH IMPLICATIONS FOR PHOTODYNAMIC THERAPY.

**Prabhakar Misra**, Howard University, Washington, D.C. The technique of laser-mediated release of organic dyes from liposomes can be used for localized photothermal delivery of dye-drug complexes to destroy specific tumor tissue sites. Targeted and efficient release of organic dyes from liposomes has been accomplished via excitation using 10 ns FWHM laser pulses. A modified solvent evaporation-rehydration technique was used to encapsulate the sulforhodamine dye within the phosphatidylcholine liposomes. Excess unincorporated dye was extracted using Sephadex G-25 columns. Polycarbonate membrane filters were used to obtain vesicles of specific sizes. Liposome size distribution was classified by a laser-based quasi-elastic light scattering technique. The average diameter of unfiltered vesicles was  $2.0 \pm 0.7$  microns. Absorption spectra of the dye-liposome complexes were recorded with a UV-VIS spectrophotometer. Tris-buffered and diluted liposomes were transferred to capillary tubes and longitudinally

\*The author(s) acknowledge that proprietary disclosure is required for material presented in the abstracts denoted by an asterisk.

excited with 532 nm, 10 ns wide laser pulses from a frequency-doubled Nd:YAG laser, which corresponded to pulse energy densities in the range 0.2-2.0 J/cm<sup>2</sup>. Irradiated liposomes were subsequently placed transversely in the path of a second laser beam of wavelength 585 nm. Fluorescence from the disrupted liposomes passed orthogonally through a monochromator set at 615 nm and then detected by a photomultiplier tube - picoammeter combination. Typically, for a dye concentration of 50 mM, and a pulse energy density of 1.5 J/cm<sup>2</sup>, the efficiency of dye release exceeded 70%. Our results indicate that the efficiency of dye release from liposomes is governed primarily by laser pulse energy density, dye concentration, liposome size and ambient temperature. These results have significant implications for photodynamic therapy, which essentially involves a process that combines a photoactive drug (e.g. photofrin) with directed low-energy light from a laser to attack and destroy cancer cells at specific sites in a patient's body.

## 3

### Quantification of laser-induced damage of the retina by fluorescein angiography

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**Purpose.** An *in vivo* study was done to establish the interest of fluorescein angiography in the quantification of laser-induced damage in ophthalmology.

**Method.** This study was carried out on rabbit eyes with a 810 nm diode laser (Ø: 500 µm, pulse duration: 1 s, power: 100 mW to 400 mW). Fluorescence measurements were performed with a fundus camera connected to a fluorescence imaging system. The fluorescence intensity kinetic was evaluated by mathematical modeling. Lesions were correlated to laser parameters and to histologic data.

**Results.** Image analysis shows that the laser lesions stained progressively. Fluorescence appears first at the borders of the lesion exhibiting a fluorescent ring. A progressive increase of the fluorescence into the central zone is observed. The maximum fluorescence intensity into the center of the laser spot is obtained after a delay depending on the laser energy. Below 100mW/cm<sup>2</sup>, lesions are detectable by fluorescence imaging only. A fluorescence plateau appears for a threshold light dose above 200mW/cm<sup>2</sup>. Mathematical modeling demonstrates that quantitative assessment of laser-induced damage to the retina is feasible using fluorescence imaging.

**Conclusion.** The quantification of fluorescence staining in terms of both intensity and time can contribute to a better quantification of laser-induced damage and can be correlated to histologic observations. So, a photocoagulation grading can be obtained instead of retina discoloration which is usually the parameter used by ophthalmologists. Fluorescein angiography has long been useful for the evaluation of vascular disorders, it could maybe considered for the quantification of diode laser induced damage related to the treatment of choroidal neovascular membranes or diabetic macular edema

## 4\*

### OSHA UPDATE: NEW GUIDELINES FOR THE SAFE MANAGEMENT OF SURGICAL SMOKE

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Over the past three years, a number of healthcare professionals and organizations have worked diligently with OSHA to develop a regulatory approach to the management of surgical smoke exposure. Controversy and debate aside,

research has defined the hazard, industry has produced the engineering control measures, and it is now up to the professional medical community to mandate appropriate work practices designed to comply with the new guidelines. The document just released by OSHA is the foundation for that mandate. risk managers, infection control officers, safety officers, operating room and clinic managers, administrators, directors of research laboratories, staff in private surgical facilities, mobile laser service vendors and recipients, and all nursing personnel and clinicians, should become familiar with the document and should work towards implementation and consistent compliance in their practice settings. OSHA serves the professional community as an advocate for maintaining a safe working environment, and has come to the forefront of a difficult and long standing controversy, with a clear stand on protection for all healthcare workers against exposure to this occupational health hazard.

## 5

### COMPARISON OF THE EFFECTS OF THE ERBIUM:YAG AND THE CARBON DIOXIDE RESURFACING LASERS ON THE SUPERFICIAL PIGMENTATION AND VASCULATURE OF THE SKIN WITH SPECIALIZED PHOTOGRAPHY

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The purpose of this presentation is to compare the changes to the superficial vasculature and pigmentation of the facial skin in patients who have had resurfacing with the Erbium:YAG and Dioxide lasers. Standard photography, cross-polarized and parallel polarized photography and ultraviolet light photography was used before and after treatment sequences. The effects of cutaneous laser resurfacing on superficial pigmentation and vasculature could then be quantified. Results: Ultraviolet light photography is best utilized for demonstrating the changes to superficial pigmentation after cutaneous laser resurfacing. Parallel polarized photography is best for demonstrating superficial vascular changes. Specialized photography is a useful teaching tool for patients with chronic photography and aids in measuring clinical outcomes of cutaneous laser resurfacing.

## 6\*

### Infrared Thermal Imaging: Evaluation of Hair / Skin Temperature Changes During Laser Depilation and Practical Clinical Applications

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**Introduction:** Efficacy of the hair removal laser systems is highly variable and the parameters for optimal safety and efficacy are poorly understood. These parameters include hair color, shaft diameter, stage of hair in the growth cycle, and a currently unknown anatomical target for permanent reduction. Progress in defining these issues has been hindered by these many variables and requisite lengthy clinical trials.

**Purpose:** To study the laser / hair interaction event using infrared thermal imaging. To provide practical correlation between Q switched Nd:YAG laser induced temperature changes of various types / colors of skin / hair and clinical results.

**Methods:** A new high peak power Q switched Nd:YAG laser was evaluated with an infrared thermal imaging system. Treatments were applied to Fitzpatrick Type I – VI hair-bearing skin and various hair colors. Evaluations were made by varying fluence, pulse duration, and pulse repetition rates.

**Results:** The infrared imaging demonstrated the thermokinetic response of different hair colors and skin types during the laser to hair / skin interaction. Selective temperature rise of hair shafts was observed after a single pulse, and outward diffusion of heat into the surrounding skin with stacked pulses. These images and observed temperature changes and their corresponding effects will be presented in detail. Hair color, background skin type, and laser parameters are major variables for safety and efficacy in this complex treatment equation.

**Conclusions:** Thermal imaging is a useful tool for helping develop optimal treatment parameters by wavelength and other parameters for Fitzpatrick Type I – VI skin. This thermokinetic information has very practical applications for everyday clinical therapy.

## BIOSTIMULATION

### 10

#### LACK OF STIMULATORY EFFECT OF LASER IRRADIATION 660nm AT VARIOUS RADIANT EXPOSURES UPON A RADIATION IMPAIRED WOUND HEALING MODEL IN MURINE SKIN

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The use of low intensity laser therapy (LILT) as a therapeutic modality has become popular in a variety of clinical applications including the promotion of wound repair. Although the evidence base for such application remains sparse, recent studies have demonstrated a number of quantifiable photobiological effects associated with such therapy<sup>1,2</sup>. In the present study, the effect of laser irradiation at various radiant exposures upon a radiation impaired wound model in murine skin was investigated. The study included two phases; in phase one, male Balb/c mice (n=36; age matched at 12 weeks) were randomly allocated to 3 experimental groups (n=12 each group). In all groups a well-defined area on the dorsum was exposed to 20 Gy (Siemens Stabilipan X-ray machine). Seventy-two hours post-irradiation all mice were anaesthetised and a 7mm square wound made on the dorsum. All wounds were videotaped alongside a marker scale (3 times weekly) until closure was complete. In Groups 2 and 3 mice were treated with laser irradiation (0.5 and 1.5J/cm<sup>2</sup> respectively) 3 times weekly using a 660nm GaAlAs laser unit (5KHz; 15mW; Omega Laser Systems, London, UK). Subsequently, the area of each wound was measured from video using an image analysis system (Fenestra 2.1). In phase two, 2 experimental groups were included (n=12 each group); the protocol was identical to that described for phase one, however, mice in group 2 were treated at a radiant exposure of 4.0J/cm<sup>2</sup>. Statistical analysis of data in phase one using analysis of variance showed that treatment with 0.5 and 1.5J/cm<sup>2</sup> had no effect upon the rate of closure in this animal model (p=0.27). Results from phase two also showed no effect upon the rate of wound closure (p=0.56). These findings demonstrate that LILT at the parameters investigated failed to accelerate the closure of full-thickness skin excisional wounds in this animal model and thus provide no evidence of the claimed stimulatory effects of this modality at these parameters.

1. Funk JO, Kruse A, Kirchner HJ. Cytokine production after helium-neon laser irradiation in cultures of human peripheral blood mononuclear cells. *J Photochem Photobiol* 1992; 16:347-55.

2. Baxter GD, Walsh DM, Allen JM, Lowe AS, Bell AJ. Effects of low intensity infrared laser irradiation upon conduction in the human median nerve in vivo. *Exp Physiol* 1994; 79:227-34.

### 11

#### Effects of GaAlAs diode laser on the axial pattern skin flap in rat model

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In the present study we examine the mechanisms of the effects of low power laser on peripheral blood flow on the axial pattern flap in rat model.

#### Materials and Methods

[Experimental model] A total of 30 male rats (approximately 3weeks old, weighing 250-300g) were used. The animals were randomly divided into three groups of 10 animals each for studying peripheral blood flow and flap survival after five days. We used an axial pattern skin flap which had a dominant vessels, we divided into a control group, a group which received direct irradiation at the dominant vessel and a group which received irradiation at the distal point of the flap. The target point for laser irradiation was thus direct irradiation of the dominant vessel or the distal end of the flap. Each flap was raised and the peripheral blood flow was assessed by laser speckle flowmetry. We then investigated the differences in blood flow comparing laser irradiated or with nonirradiated flaps, and also compared the effects according to the target point of irradiation. Following the laser speckle flowmetry the flaps were sutured back in place. All rats were observed for five days postoperatively to assess viability of the flaps.

[Laser System] A gallium aluminum arsenide (GaAlAs) diode laser system from NIIC Co. Ltd (Japan) was used. The wavelength was  $810 \pm 10$  nm, at an output power of 100mW on an irradiated area of 0.0054 cm<sup>2</sup>, giving an incident power density of 18.5 W/cm<sup>2</sup>.

#### Results

During irradiation, the blood flow rate was better than the experimental groups before irradiation or the unirradiated control. After irradiation, there was better perfusion throughout the experimental flaps than the control flaps. Regarding the condition of the survived areas of the flaps at the 5<sup>th</sup> postoperative days, there was a clear difference between the irradiation group and control group. The irradiated flaps had greater survival areas than the control flaps. In the axial pattern skin flap, comparing the difference results between the target points of irradiation.

#### Conclusions

Our studies showed the effects on the blood flow after irradiation. The laser irradiated flaps compared to the control non irradiated flaps. The irradiated flaps are better perfusion than the control flaps. Much larger areas of enhanced perfusion were clearly seen more distally in the experimental flaps. The Diode laser irradiation produced a greater survival area on the flap, and the increase of the vascular perfusion seems to be a key to that.

### 12

#### THE EFFECT OF LOW-LEVEL LASER IRRADIATION ON LYMPHOCYTES FROM PERIPHERAL BLOOD.

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The therapeutic application of low-level laser irradiation (LLLT) in various fields has aroused interest in the action of laser light on whole organ systems, including its interaction with whole blood. The purpose of this study was to demonstrate the biostimulation effect of argon-dye laser (660nm) and diode laser (830nm) light on lymphocytes in the presence or absence of erythrocytes. **Methods:**  $2 \times 10^6$  cell /ml lymphocyte suspensions were irradiated at influences of 0-5 J/ cm<sup>2</sup> in the absence or presence of erythrocytes (diluted "whole" blood). The following parameters were monitored to demonstrate alterations in the biological and biochemical functions of lymphocytes: PHA stimulated proliferation by H<sup>3</sup>-thymidine uptake, cell mediated cytotoxicity, malonaldehyde (MDA) concentration as an indicator of lipidperoxidation, and superoxide-dismutase (SOD) for the antioxidant capacity. **Results:** Irradiation at 660nm in the presence of erythrocytes significantly enhanced the proliferation response of lymphocytes to PHA. Maximal response was detected at 3J/ cm<sup>2</sup>. Stimulation indexes were  $42.6 \pm 5.72$  for non-irradiated, and  $148.8 \pm 24.7$  for irradiated samples ( $t = 10.26$ ,  $p < 0.05$   $n=6$ ). No stimulation occurred in the absence of PHA. Laser irradiation at 830nm resulted in a maximal interaction at fluence of 1.5J/cm<sup>2</sup>. Differences in the stimulation indexes were less expressed. In absence of erythrocytes the effect of irradiation showed a weak dose-response relation. No significant change could be detected in cell mediated cytotoxicity. MDA concentration was elevated (2-4 times) after irradiation when erythrocytes were present, and was more pronounced if the cells were incubated after the treatment. These results indicate that catalyzed reactive -oxygen- substances play an integral role in laser light interaction with whole blood.

## 13

## GALLIUM-ARSENIDE LASER BIOMODULATION OF THE CELLULAR OXIDATIVE STRESS

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The aim of the study was to test if low power laser biomodulation is related to the oxidative stress mediated through cellular lipid peroxidation. Pulsed GaAs semiconductor (LAIR, Zagreb, Croatia), 50 W peak power, 905 nm wave length was used at the same energy density of 1.05 J/cm<sup>2</sup> or 3.10 J/cm<sup>2</sup> for the treatment of HeLa cell cultures. Laser treatment was combined with the use of toxic concentration (100 μM) of lipid peroxidation product 4-hydroxynonenal (HNE) known as a "second toxic messenger of free radical". The cells were afterwards used either for the viability analysis according to the Trypan-blue exclusion test and MTT bioassay or for the immunocytochemistry applying monoclonal antibodies specific for HNE-histidine conjugate. The same antibodies were also used to analyse the presence of HNE-protein adducts in the culture medium. We found that lasing itself did not generate HNE, hence, the GaAs irradiation applied did not induce oxidative stress associated with lipid peroxidation. However, lasing increased the incidence of HNE positive cells for the HNE treated cultures, irrespective of the energy density, while changed morphology of the cells indicated toxic effects of the treatment used. Such effects were more pronounced if the cells were first lased and then cultured in presence of HNE, than if they were pre-treated by HNE and then exposed to laser irradiation. Moreover, laser pre-treated cells released in culture media HNE-protein conjugates while their viability was decreased in comparison to the cells treated only by HNE or by lasing alone. Thus, we found that GaAs laser treatment modulates cellular oxidative stress.

## 14

## BIOLOGICAL INFORMATION MODEL OF LOW INTENSITY LASER FOR LASER BIOSTIMULATION.

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In this paper, we have put forward the biological information model of low intensity laser (BIML) on cells and autonomic-nervous-subsystem, CBIML and ABIML, respectively, and shown them in terms of time approach on generation of biological information. According to CBIML: laser couples with intracellular messenger through the chromophore absorption in the cell membrane: hot-color (red, orange, yellow) activates cAMP phosphodiesterase through G<sub>i</sub> protein or activates phosphoinositide phospholipase C through G<sub>q</sub> protein, or activates one of receptor-associated kinases: cAMP↓; cold-color (green, blue, violet) activates adenylate cyclase through G<sub>s</sub> protein: cAMP↑. As cAMP also mediates the response of autonomic nervous subsystem in the body, we have ABIML: cold color excites sympathetic subsystem and hot color excites parasympathetic subsystem.

Their successful applications at the cellular level and the clinical level from the viewpoints of the integrated western and Chinese traditional medicine show that CBIML holds for laser-cell interaction, and CBIML and ABIML hold for body response through the intravascular laser irradiation on blood.

## 15

## Study on Laser Medicine Comprehensive Therapy in Improving Therapeutic Effectiveness of Treating Cerebral Infarction and Reducing Maim Ratio

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As a new special distinguishing therapy, laser medicine comprehensive therapy uses a multiple of laser technology to treat cerebral infarction and its sequel, to restore function, to lower maim ratio and mortality, to cut down medication and cut short the course of treatment. According to the statistics analysis (120 cases) of about ten thousands patient times since 1993 the perfect effect of the treatment is more remarkable than that of the conventional one of neuromedicine. The therapy is different from various simple laser irradiation blood therapy (including UV radiation blood therapy) at present in our country. It is a comprehensive therapy combined with clinical medicine, whose dominant part is LBIO (laser blood irradiation and oxygen retransfusion therapy), and is supplemented by various laser technologies, such as PLBS (pulse CO<sub>2</sub> laser biostimulation) and LPDCM (laser photodynamic in Chinese medicine), etc.

Key words: cerebral infarction & sequel of apoplexy: laser blood irradiation and oxygen retransfusion therapy (LBIO); pulse CO<sub>2</sub> laser biostimulation (PLBS); laser photodynamic in Chinese medicine (LPDCM)

## 16

## SOFT TISSUE INJURY DURING SPORT ACTIVITIES AND TRAFFIC ACCIDENTS - TREATMENT WITH LOW LEVEL LASER THERAPY: A Multicenter Double Blind, Placebo Controlled Clinical Study on 132 Patients.

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Guided by successful application of Low Level Laser Therapy (LLLT) on other types of soft tissue damage, we have decided to apply this treatment modality as monotherapy on soft tissue injuries which occurred during sport activities and traffic accidents, in double blind, placebo controlled fashion. We have treated 132 patients in two laser centers (Switzerland, n=94 and Croatia, n=38). Patients were suffering from the injury of soft tissue as follows: distortion and sprain of the ankle, lesion of Achilles tendon, dislocation of the knee, shoulder and interphalangeal joints, wrist and cervical spine injuries and both types of epicondylitis. All patients represented acute cases with unilateral and bilateral form of the injury.

Two types of irradiation techniques were used: direct, skin contact technique for treatment of Trigger Points (TPs) and scanning technique for irradiation of larger surface area. Types of laser devices used to perform these treatments were infrared diode laser (GaAlAs) 830 nm continuous wave for treatment of TPs and HeNe 632.8 nm wavelength combined with infrared diode laser 904 nm pulsed wave for scanning technique. Doses applied were exactly measured and calculated in Joules per TPs and cm<sup>2</sup>. Results were observed and measured according to the clinical parameters like: redness, heat, swelling, pain, loss of function. These findings were compared to the control group of patients treated with classic therapeutic procedure and statistically analyzed. The results have demonstrated that the recovery process was accelerated (35-50%) in 85% of patients treated with LLLT compared to the control group of patients. Due to effective functional recovery, professional athletes were able to return to training and sport competition significantly earlier than those treated with classic therapeutic procedures. The results and the advantages obtained in this clinical study proved once again the efficacy of LLLT as new way in the treatment of soft tissue injuries.

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### APPLICATION OF LOW LEVEL LASER THERAPY ON OPERATED SPORT AND TRAFFIC ACCIDENT INJURIES: A Randomized Clinical Study on 74 Patients with Control Group.

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In the initial part of our research we have conducted a randomized controlled animal study, where we have evaluated the effects of laser irradiation on the healing of surgical wounds in rabbits. The ways of application of Low Level Laser Therapy (LLLT) on human body are analogous to those of similar physiological structure in animal tissue. Therefore this study was continued with LLLT of human body. It is well-known that application of laser light can accelerate the healing of the skin, but it can also improve the healing of deeper structures like ligaments, tendons, capsules, etc. Current clinical study was performed on 74 patients suffering from the injuries on the following anatomic locations: ankle and knee bilaterally, Achilles tendon, epicondylus, shoulder, wrist, interphalangeal joints unilaterally. All patients were subject to surgical procedure prior to LLLT. The remaining group of patients represented control which was treated with classic therapeutic procedure. Two types of laser devices were used: infrared diode laser (GaAlAs) 830 nm continuous wave for treatment of TPs and HeNe 632.8 nm combined with diode laser 904 nm pulsed wave for Scanning procedure, both applied as monotherapy during current clinical study. The results were observed and measured according to the following clinical parameters: redness, heat, pain, swelling, loss of function, and finally postponed to statistical analysis. The results have demonstrated that the wound healing was significantly accelerated (25-35%) in group of patients treated with LLLT comparing to the control group. Pain relief and functional recovery of patients treated with LLLT were significantly improved comparing to the untreated patients. In conclusion, aside of accelerated wound healing, the main advantages of LLLT of postoperative sport and traffic accident injuries are prevention of side effects of drugs, significantly accelerated functional recovery, earlier return to work, training and sport competition comparing to the control group of patients, as well as cost benefit.

## 18

### SYSTEMIC EFFECTS OF LOW INTENSITY LASER IRRADIATION: RESULTS IN PATIENTS WITH DIABETIC MICROANGIOPATHY AND LITERATURE REVIEW

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Low intensity laser irradiation has been shown to induce wound healing in conditions of reduced microcirculation which is in part explained by systemic effects. We investigated a potential systemic effect of low intensity laser irradiation on skin blood circulation in patients with diabetic microangiopathy and give an overview of the relevant literature.

Patients with diabetic microangiopathy were randomized to receive either a single low intensity laser irradiation with a dose of 30 J/cm<sup>2</sup> or a sham-irradiation over the forefoot region in a double-blind, placebo-controlled clinical study. Skin blood circulation by means of temperature-recordings over forefoot region was detected by infrared-thermography.

Following a single transcutaneous low intensity laser irradiation a significant rise in skin temperature was noted over both the laser and sham irradiated forefoot regions.

The data from this study show a significant increase in skin circulation due to athermic laser irradiation in patients with diabetic microangiopathy and point to the possibility of inducing systemic effects. This observation is accordance with results in the literature.

## 19

### INCREASED DERMAL NEOVASCULARIZATION AFTER LOW INTENSITY LASER THERAPY OF A CHRONIC RADIATION ULCER

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Recently, low intensity laser irradiation has gained increasing interest as a non-invasive method for the induction of wound healing in recalcitrant ulcerous lesions in patients with diabetes and radiodamage. We therefore investigated whether the process of laser-induced wound healing is associated with an increase in the number of dermal capillaries in a patient suffering from a recalcitrant ulcer following radiotherapy.

A 10mW Helium-neon laser (wavelength: 632.8nm) was utilized at a dose of 30J/cm<sup>2</sup>. A video measuring system (VMS) was used to determine the number of dermal vessels in the ulcer before and after laser treatment.

After seven irradiations the ulcer had healed completely. Light microscopy in combination with a VMS showed a significant increase ( $p < 0.001$ , Student's t-test) in the number of dermal capillaries after laser treatment. We demonstrate the complete healing of a chronic radiation ulcer after low intensity laser irradiation. By means of light microscopy in combination with a VMS we found a significant increase in the number of dermal vessels after laser therapy in the reepithelialized skin compared to pre-treatment conditions.

## 20

## LOW POWER DIODE LASERS IN CLINICAL PRACTICE

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The aim of this study is to verify the comparative efficacy of different diode lasers in rheumatic disorders. We considered 748 patients splitted into four groups: A - treated with IR pulsed diode laser (output power about 3.5 mW), B - IR diode laser with continuous emission (3.5 mW power), C - treated with both IR diode laser and red diode laser (8 mW power), and D - patients exposed to placebo laser. The energy dose per point was about 1 J. We irradiated a various number of points function of the disease. The results were appreciated using a pain scale for all the patients and cutaneous echographies (only for some of the patients from every group).

The positive results were 62.8% for IR pulsed diode, 65.6% for continuous IR diode, 83.5% for both diodes, 40.5% for placebo laser. Secondary, we compared, with the same protocol, IR continuous diode laser (178 patients) with noncoherent (7 mW power - 162 patients) and with placebo laser (172 patients). Positive results were obtained in 65% of the cases for diode laser, 50.6% for noncoherent diode and 40.5% for placebo laser.

We conclude that there are no clinical differences between pulsed and continuous IR diode laser. The best clinical results were obtained when IR and red diode were used together. IR diode laser is superior to noncoherent diode in clinical practice. Diode lasers are superior to placebo laser. So, diode lasers are a useful therapeutical means for rheumatic diseases.

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## LOW ENERGY LASER TREATMENT IN LICHEN PLANUS AND FINGERS PULPITIS INFECTIONS

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We tried to verify the efficacy of low energy lasers (LEL) in the treatment of fingers pulpitis infections and lichen ruber planus.

We splitted the patients into three groups: laser group - 24 patients, placebo laser group - 11 patients, and a group treated with classical therapy - 19 patients.

The laser used was a red diode with continuous emission, 8 mW output power, 668 nm wavelength and 4 mm spot size. The results were appreciated not only by clinical features, but also by histological samples and cutaneous echographies done before and after the treatments.

We obtained good objective results at 83% of the patients from laser group, compared to 45% from the placebo laser group, and at 63% of the patients from the group treated with classical therapy.

We conclude that LEL can be a possible therapy for lichen ruber planus and fingers pulpitis infections.

## CARDIOVASCULAR

## 25\*

**TRANSMYOCARDIAL LASER REVASCULARIZATION: A RANDOMIZED CLINICAL STUDY WITH 12-MONTH FOLLOW-UP**  
Kamuran A. Kadipasaoglu, O. H. Frazier, Laurie A. Stutts, Denton A. Cooley  
Texas Heart Institute

**Purpose:** The safety and efficacy of transmyocardial laser revascularization (TMLR) with a CO<sub>2</sub> laser was evaluated in 36 patients with refractory angina secondary to coronary artery disease.

**Methods:** The first 23 patients were randomized to TMLR (n=12) or maximal medical management (n=11). After randomization was complete, the next 13 patients were assigned to TMLR. Demographics and medical and surgical histories were similar for all 3 groups. All TMLR patients were pooled for follow-up analysis.

**Results:** Clinical assessment of 18 TMLR patients at 12 months showed that angina was reduced by 2 or more Canadian Cardiovascular Society classes in 10 (56%) patients, unchanged in 1 patient (6%), and increased in 7 (4%) patients. Of the 7 with increased angina, 2 patients had PTCA or stent(s) for *de novo* occlusion, and 2 were hospitalized for CIIF, one of whom died on day 96. A total of 3 other patients died, 2 perioperatively of arrhythmia and 1 of aspiration pneumonia on day 70. Of 11 medical management patients, 6 (55%) were hospitalized for unstable angina or CIIF, 1 (9%) was stented for *de novo* occlusion, and 2 (18%) had no change in angina at 12 months. Two medical management patients (18%) died suddenly at home. Six (55%) were crossed over to TMLR upon stabilization of angina or completion of follow-up. Of these, 1 died of CHF on day 43; 1 was stented on day 90. Only 1 showed clinical improvement. The percentage of myocardial regions in which perfusion by <sup>201</sup>Tl-SPECT improved over baseline was 48% in 7 TMLR patients and 0% in 3 medical management patients assessed at 12 months. Exercise tolerance (bicycle ergometer) improved by 53% over baseline in TMLR patients and deteriorated by 22% in medical management patients. Perfusion data agreed with clinical status in 8 (80%) of these 10 patients.

**Conclusion:** Over a period of 12 months, TMLR reduced anginal symptoms and improved myocardial perfusion and exercise tolerance without increasing mortality and morbidity in this limited subset of patients with chronic stable angina.

## 26

**ACUTE EFFECTS OF TRANSMYOCARDIAL REVASCULARIZATION ON LEFT VENTRICULAR FUNCTION IN INTRACTABLE ANGINA.**

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Luis A.F.Lisboa\*, Luis A.M.Cesar\*, Adib D. Jatene\*.

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**Background/Purpose:** Despite the advances of interventional cardiology and cardiac surgery, there is a significant group of patients w/ intractable angina that remains resistant to all traditional treatment modalities, such as clinical therapy, angioplasty and bypass surgery. For such group, there is an alternative therapy, known as Transmyocardial Laser Revascularization (TMLR). This therapy has been suitable for intractable angina case, while creating channels direct to the ischemic myocardium, which enable a good zone revascularization. The resulting drills can induce edema formation, that can be harmful for the left ventricular function. In this study, the efficiency of TMLR and its hemodynamic function have been evaluating.

**Study Design (M/M):** Patients enrolled in this study presented intractable angina w/ diffuse coronary artery disease keeping good left ventricular function. This trial started in February of this year. All patients were monitored w/ Swan-Ganz catheter a. echocardiographic transesophageal (TEE) during the laser procedure. Just in one case combined approach w/ coronary artery bypass grafting was done. All the others were submitted to a small left thoracotomy for TMLR w/out pump. We employed high energy (800 W) CO<sub>2</sub> laser (The Heart Laser, PLC Med.Syst., Inc.), in order to reperfuse the ischemic myocardic zone. We drilled 24 - 46 transmural channels, applying 20 to 40 J. per area.

**Results:** We have not detected any unstable hemodynamic alteration during the procedure or subsequently. All shots were effective in most of patients (100%) even though two of patients had less efficiency due to a fat epicardium (80%), also the penetration was always confirmed by TEE. Basically, all patients had a good hemodynamic recovery and they didn't present any arrhythmia during the hospital staying, confirming a stable left ventricular function.

**Conclusion:** All our patients had a good evolution w/out complications during the perioperative period. In the patients w/ 6 mo follow-up no angina was noted. No morbidity and mortality was encountered until today. Thus, these results suggest that TMLR is very effective for patients w/ end-stage coronary artery disease, improving event free survival, angina class and quality of life.

## 27\*

### TRANSMYOCARDIAL LASER REVASCULARIZATION AS ADJUNCT TO CABG: PRELIMINARY FINDINGS OF A RANDOMIZED STUDY

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**Purpose:** We evaluated the utility of adjunctive Transmyocardial Laser Revascularization (TMLR) in lowering perioperative mortality and morbidity of CABG in patients with distal, diffuse coronary artery disease.

**Patients and Methods:** Between December 1996 and June 1998, 21 patients, (age  $60 \pm 8$  yr., 6 women) with refractory distal, diffuse coronary artery disease were randomized for coronary artery bypass grafting (CABG) either with adjunctive TMLR (n=11) or without TMLR (n=10). The left ventricular ejection fraction was  $46 \pm 11\%$  and 10 patients had previous sternotomies ( $0.6 \pm 0.7$  per patient). Intergroup differences were nonsignificant with respect to all preoperative characteristics except use of the left internal mammary artery (LIMA) for previous CABG (TMLR group: 5, all patent; non-TMLR group: 0;  $P < 0.001$ ).

**Results:** In the TMLR group,  $37 \pm 2$  channels were drilled with a CO<sub>2</sub> laser before cardiopulmonary bypass (CPB) was initiated. In TMLR and non-TMLR groups, respectively, CPB time ( $110 \pm 38$  vs.  $154 \pm 58$  min), aortic cross-clamp time ( $65 \pm 25$  vs.  $81 \pm 45$  min), number of bypasses ( $3.0 \pm 0.6$  vs.  $3.6 \pm 0.7$ ), and inotropic usage during weaning from CPB (7 vs. 6 patients) were not significantly different. The LIMA was used in 2 TMLR patients vs. 8 non-TMLR patients ( $P < 0.001$ ). Two TMLR patients required intra- or postoperative intraaortic balloon pump (IABP) placement. Six non-TMLR patients had IABP; two of whom also necessitated a left ventricular assist device. One TMLR patient (10%) died at home on postoperative day (POD) 186, of complications of systemic lupus erythematosus. Four non-TMLR patients (40%;  $P < 0.001$ ) died of arrhythmias/cardiac arrest (n=2; PODs 1 and 2) and multi-organ failure (n=2; PODs 2 and 5). For surviving patients, the average hospital stay was  $15 \pm 3$  (TMLR) versus  $8 \pm 4$  days (non-TMLR) ( $P = \text{NS}$ ).

**Conclusion:** In this randomized pilot study, adjunctive TMLR significantly lowered the perioperative mortality and the need for mechanical circulatory support after CABG in patients with technically challenging coronary anatomy and pathology.

## 28

### INTRAVASCULAR RED LASER THERAPY REDUCES RESTENOSIS FOLLOWING CORONARY STENTING

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**Background:** High restenosis rate remains a limiting factor for PTCA and stenting. Recently, the use of intravascular red laser light (IRLLT) has been shown to be effective in different animal models and in humans in the reduction of restenosis rate. The objective of the present study was to evaluate the effect of IRLLT on restenosis following stenting procedures in de novo lesions.

**Methods:** 103 patients have been treated with intravascular red laser (650nm, 10mut, 3 min) in conjunction with coronary stenting procedures. The mean age was  $65 \pm 8.6$  years. A total of 111 lesions were treated. Lesion characteristics were type A lesions 11, type B 67, type C 33, calcified lesions 44.1%, angulated lesions 14.4%, with thrombus 5.4%, with ulceration 5.8%, eccentric lesions 58.55%. The mean length of the lesion was  $16.8 \pm 2.5$ mm. The preRD and preMLD were  $2.93 \pm 0.10$ mm, and  $0.75 \pm 0.63$ mm respectively with a mean stenosis of  $73.1 \pm 14.0\%$ .

**Results:** After the stenting procedure and laser irradiation, MLD and the stenosis were  $2.65 \pm 0.47$  mm and  $16.8 \pm 3.6\%$  respectively. No minor or major complications were recorded during the entire study. All patients were followed up as depicted in the protocol. 56 patients underwent angiographic restudy at 6 months which revealed that restenosis occurred in 8 patients (14.2%). In arteries greater than 3mm (n=18), restenosis rate was 0%. In arteries 2.5-3mm (n=29), the restenosis rate was 13.7%. However, in arteries less than 2.5mm (n=9), we observed 44.4% of restenosis.

**Conclusions:** Intravascular red laser therapy reduces restenosis in patients following stenting in coronary arteries greater than 2.5mm in diameter.

## 29

### THE PINERO PRE-CARDIAC SURGERY PROTOCOL

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The purpose of this study is to show a significant advantage of NdYag laser usage in the treatment of Periodontal Infection prior to Cardiovascular surgery by substantially reducing orally induced bacteremias.

From the oral cavity, oral organisms have been traced to the heart. The consequences often have been fatal-mediastinitis, endocarditis, myocarditis and the most well known bacterial endocarditis.

Transient bacteremias are associated with extraction of teeth and periodontal treatment. Positive blood cultures in post extraction blood cultures average about 52% which is considerably higher than the 10-15% positive cultures reported for suspected bacteremias unassociated with surgery. The use of an NdYag laser has proven useful in the substantially reduction of post extraction and post periodontal surgery bacteremias in patients to undergo Cardiovascular Surgery. The NdYag laser if utilized in a curettage surgical procedure completely circumscribing any teeth in the oral cavity prior to extraction or oral surgical procedure. The laser ability to provide a bloodless field and sterility by ablation of cells and cell nuclei including those of bacteria that come in contact with the beam path.

The results show over 200 patients treated with this protocol show a 0 rate bacteremia post extraction and post periodontal surgery. Pre-operative and post-operative blood cultures demonstrated the significant decrease in bacteremias from the use of this protocol. The conclusion is a dramatic reduction of bacteremias after dental therapy in periodontally infected patients prior to their Cardiovascular surgery. This protocol shows a superior approach to treating oral infections in patients awaiting Cardiovascular surgery than the conventional non-laser approach.

## 30\*

**LASER-LIGHT SCATTERING AS A NEW METHOD FOR MEASURING PLATELET AGGREGATE FORMATION IN ARTERIES FOLLOWING BALLOON INJURY**

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Since platelet function following balloon angioplasty is critical to clinical outcomes, this study was designed to evaluate a laser-light scattering technique to measure platelet aggregate formation following arterial wall injury. Platelet rich plasma (PRP) was obtained by centrifugation of whole blood collected from 10 dogs. Both carotid arteries (CAs) were removed after sacrifice and mounted in a perfusion chamber. Intimal injury to both CAs was induced using 3.0 mm balloons (three 60 sec. inflations). PRP was perfused through the CAs. A He-Ne laser beam was split and passed through cuvettes in the tubes draining the CAs. The scattering light, from the particles in the cuvettes, was spread on the diode array of a multichannel analyzer. From the angles of incidence, the ratio of scattering light at  $1^\circ$  to  $5^\circ$  represented the particle size distribution. Platelet aggregates were also measured by Coulter counter and compared to the laser method. Results by Coulter counter demonstrated that particle size increased from  $29.9 \pm 2$  to  $62.3 \pm 7 \mu\text{m}^3$  (mean  $\pm$  SE);  $p < 0.0005$ . Using laser-light scattering, angular light ratio increased from  $114.4 \pm 6$  to  $397.4 \pm 60$ ;  $p < 0.0004$ . The correlation between the two methods was  $r = 0.77$ ;  $p < 0.005$ . In conclusion, these data suggest that laser-light scattering correlates well with the Coulter counter method and has the advantage of continuous measurement of platelet aggregate formation. Laser-light scattering may be developed to assess platelet aggregate formation *in vivo* during drug delivery in interventional procedures.

## 31

**IN VITRO AND IN VIVO EFFECT OF SUB-ABLATIVE PULSED INFRARED LASER IRRADIATION ON VASCULAR CELLS**

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**Background:** Restenosis following coronary interventions may be attributed to proliferation and migration of smooth muscle cells into the intima. The purpose of the study was to determine the effect of low power (sub-ablative) infrared laser radiation on viability of vascular smooth muscle cells.

**Methods:** Confluent cultures of human aortic smooth muscle cells were irradiated with low power (260 millijoules, pulse duration 160 ns) infrared (1064 nm) radiation from ND-YAG laser (Alien Technology) transmitted via optical fiber. Normalized viability index (NVI) detected with nondestructive Alamar Blue assay and direct cell count were studied. Our experiments demonstrated cytotoxic effects of lower power infrared laser irradiation. NVI of irradiated cultures was  $48.5 \pm 3.1\%$ . To evaluate the immediate impact of lower power infrared radiation on the vascular wall, 10 nonatherosclerotic rabbit aortas were subjected to intra-arterial irradiation via a fiberoptic through a 20 mm laser balloon. Immediately after laser irradiation, vessels were fixed *in vivo* at harvest with 10% formalin at 80 mmHg, processed and stained with hematoxylin and eosin and Movat's. Histologic analysis revealed a highly acellular medial layer.

**Conclusions:** Low power sub-ablative pulsed infrared laser irradiation is cytotoxic to vascular smooth muscle cells and may contribute to reduction of myointimal hyperplasia.

## 32

**THROMBUS INTERACTION WITH MID-INFRARED LASER: LESSONS FROM MULTI CENTER STUDY**

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**Purpose:** This study evaluated the application of mid-infrared laser angioplasty in the treatment of coronary artery lesions. The clinical results of laser-thrombus interaction were analyzed because of clinical relevance to the treatment of patients with ischemic heart syndromes.

**Methods:** Laser angioplasty (Ho:YAG, 2.1 micron, 5 Hz) was performed on 1,862 consecutive patients with a mean age of  $61 \pm 11$  years. Clinical indications included unstable angina (69%), stable angina (20%), acute infarction (6%), and positive exercise test (5%). Complex lesion morphology included eccentricity (62%), total occlusion (27%), long lesions (14%), and saphenous vein grafts (11%). 30% of the target lesions contained coronary thrombus.

**Results:** 93% procedural success was achieved. The presence of thrombus within the target lesion was a predictor of *procedural success* (OR=2.0 [95% confidence interval 2.0,4.0],  $p = .04$ ). Bifurcation lesions (OR 0.5 [95% confidence interval 0.2,1.0],  $p = .05$ ) and severe tortuosity of the treated vessel (OR=0.4 [95% confidence interval 0.2,0.9],  $p = .02$ ) were identified as significant predictors of *decreased* laser success. Calcium within the lesion was associated with *reduced* procedural success (OR=0.57 [95% confidence interval 0.34,0.97],  $p = .03$ ). Complications included in-hospital bypass surgery (2.5%), Q-wave infarction (1.2%), and death (0.8%). Perforation occurred in (2.2%), major dissection in (5.8%), and spasm in (12%) of patients. Six-month angiographic restenosis was documented in 54% of patients.

**Conclusions:** The interaction between laser and thrombus predicts procedural success. As thrombus frequently presents in acute myocardial infarction and unstable angina the mid-infrared laser may be useful in selected patients with acute ischemic syndromes. No beneficial effects on reducing 6-month restenosis rates were observed.

## 33

**PERFORMANCE OF THE OPTIMALLY SPACED EXCIMER LASER CORONARY CATHETER** Rebecca Lippincott, William Kerker, Jerome Bellendir, Christopher Reiser, Spectranetics, Colorado Springs CO USA

**Purpose:** To evaluate the physical characteristics and ablation efficacy of an optimally spaced (OS) multiple-optical-fiber catheter, in which the fiber-to-fiber spacing at the distal tip has been expanded so that fibers subtend the entire OS surface. Excimer laser catheter models currently in use ablate holes that are typically 45–55% of the catheter tip area. **Methods:** Benchtop testing (BT): OS and Vitesse Concentric (C) catheter tips were placed in contact with fresh porcine aorta in saline while XeCl 308nm laser energy ablated the tissue. The resulting hole diameter was microscopically measured for both catheter types. Dependent variables were fluence ( $\text{mJ}/\text{mm}^2$ ), laser pulse repetition rate (Hz) and applied force. Porcine coronary model (PCM): The C and OS catheters were advanced over a guidewire and into the midportion of the left anterior descending branch (LAD), the major circumflex (Cx) branch and the right coronary artery (RCA). Radiopacity, ease of vascular access and tracking were scored on a 1 to 5 basis (1 = worst case and 5 = best case) according to the performance of each device. On additional porcine models, the laser system was activated at  $50\text{mJ}/\text{mm}^2 / 25\text{Hz}$  for 20 seconds while advancing the catheter at approximately 0.5–1.0mm per second through a straight segment of the LAD, Cx and RCA. **Results:** BT: At  $60\text{mJ}/\text{mm}^2 / 40\text{Hz}$  and 10gms applied force, the OS catheters ablated holes at least 20% larger than the C catheter. Hole diameter varied inversely with ablation rate ( $\mu\text{m}/\text{pulse}$ ) and can be maximized with



lower applied pressure. PCM: A Chi-Square Test determined that the mechanical performance of a laser catheter through coronary vasculature is independent of catheter type. A t-Test on the laser performance scores indicated that laser activation of the OS and C catheter have similar effects on arterial vessel walls. **Conclusions:** The OS catheter performed similarly to the C catheter, both mechanically and visually, while ablating a larger diameter hole and hence a greater volume of tissue.

## 34

### PHOTOACOUSTIC TISSUE DISRUPTION CREATES LASER LACUNAE<sup>®</sup> THAT PERFUSE ISCHEMIC MYOCARDIUM. David M. Harris, UCSF, Biomaterials and Bioengineering.

**Purpose:** Identify the mechanism of efficacy of transmyocardial laser revascularization (TMR).

**Methods:** Histology of porcine left ventricular myocardium immediately post-TMR. Laser channels were made with a 1.3msec duration, 6-10 Joules, 1 mm diam pulse from a CO<sub>2</sub> laser (Circulase, LLT, San Leandro, CA).

**Results:** One pulse drills a transmural channel. Acute tissue effects: (1) Laser channel, (2) Tissue splitting, (3) Radial vapor chambers and, (4) Artificial laser lacunae. The epicardial surface was either split up to 3 mm along the muscle fiber plane or the channel opening was approx. 1 mm in diameter. Within the myocardium the channel lumen varied significantly from a narrow slit to large chambers several mm's in diameter. Intramural vapor pressures opened vapor chambers radial to the axis of the laser channel along natural planes of dissection. Partially interconnected blood-filled spaces were seen both adjacent to the chambers and at radial distances up to 9 mm. These lacunae were irregular flattened discs aligned along the plane of the myocyte fibers, oriented in concentric arcs centered on a vapor chamber, and communicated with capillary networks but not directly with the channel lumen.

**Conclusion:** Explosive vaporization expands channel walls and generates an acoustic pressure wave that propagates into the surrounding tissue. High amplitude compression and rarefaction disrupts and separates the myocardium to form artificial spaces. Ruptured capillaries fill these spaces with blood (laser lacunae). Photo-acoustic tissue disruption provides immediate perfusion to a large volume of myocardium surrounding both the laser channel and the radial vapor chambers.

## DENTISTRY

## 36

### THE INTERACTION OF INFRARED LASER IRRADIATION WITH GRAMNEGATIVE BACTERIA

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The purpose of the present examination was to investigate whether there is a correlation between the antimicrobial effect of laser light and temperature rise in the dentin.

Dentin slices were irradiated in contact mode using a pulsed Nd:YAG laser at different power settings. During irradiation the maximum rise of the surface temperature on the opposite side of the samples was measured. For microbiological evaluations sterilized dentin slices were inoculated with 10 µl of bacterial suspensions and the bacteria free side was then irradiated. Another group of samples that had been treated in the same manner was investigated by scanning electron microscopy.

While temperature measurements showed a very moderate temperature rise, the microbiological evaluations proved a significant bacterial reduction compared to the untreated control group. SEM revealed dose-dependent damages of the cell morphology ranging from complete destruction of cells to surface alterations.

The results confirmed that the bactericidal effect of IR-laser irradiation cannot be explained by the temperature rise of the dentin. The impact of laser light on gramnegative bacteria is a highly selective process that causes characteristic damage and alterations of cell morphology, specific structures of the multilayered membrane system being the possible primary target. In case the cells are not immediately destroyed, cellular death might be the consequence of secondary damage that results from thermal injury.

## 37

### IRRADIATION OF HYPERSENSITIVE DENTAL NECKS WITH DIFFERENT LASERS IN VITRO.

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The effectiveness of CO<sub>2</sub> laser treatment in combination with stannous flouride gel has been demonstrated in previous studies. The purpose of this study was to evaluate the surface effects on hypersensitive dental necks not only of the CO<sub>2</sub> laser but also of the diode-, Ho:YAG - and Er:YAG laser.

After the application of either glass-clear stannous flouride gel, toothpaste, or Duraphat varnish the cervical dentine of extracted human teeth was irradiated with the lasers mentioned above. One series of teeth underwent irradiation without any prior treatment.

The examinations were carried out using scanning electron microscopy and stain penetration tests. Furthermore temperature measurements were performed.

The results of this study indicated that the complete closure of the dentinal tubules can only be achieved by the combination of the CO<sub>2</sub> laser with stannous flouride or toothpaste, whereas the other lasers leave unsealed areas.

## 38

### VERIFICATION OF CHEMICAL AND PHYSICAL BONDING MECHANISMS ON LASER-TREATED HYPERSENSITIVE DENTAL NECKS

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Conventional methods for the treatment of dental neck hypersensitivity have the great disadvantage that they have to be repeated regularly, at short intervals, to achieve permanent freedom from pain. The clinical effectiveness of laser treatment using various wavelengths has been investigated in several studies. The present examinations were carried out in order to evaluate the physical and chemical bonding mechanisms of different fluoride preparations to the dentinal surface.

Therefore, EPMA (electron probe microanalysis), XPS (X-ray photo electron spectroscopy) and XRD (X-ray diffraction) were performed.

The results of these examinations indicate that laser irradiation in combination with fluoridation results in physical and chemical bonds between the fluoride preparations and the dental neck surface. The most significant effect could be achieved using the CO<sub>2</sub> laser in conjunction with stannous fluoride gel.

### 39\*

#### TOPICAL ALA-INDUCED FLUORESCENCE IN ORAL DYSPLASIA AND MALIGNANCY.

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The objective of this investigation was twofold: (1) to determine whether laser-induced fluorescence after tissue exposure to 5-Aminolevulinic acid (ALA) can be used for detection and diagnosis of oral dysplasia and carcinoma. and (2) to identify an appropriate timepoint after ALA application for fluorescence measurements. Standard DMBA carcinogenesis was applied to one cheek pouch in 20 Syrian golden hamsters for 0, 4, 6, 8, 10, 12, 14, 16, 18, 20 weeks respectively. Prior to sacrifice, 20% ALA was applied to the cheek tissues for 30, 90 or 180 minutes. Directly after sacrifice, excised cheek tissues were cryosectioned. Significant changes in the fluorescence signature of the pathological cheek tissues were first seen 4-6 weeks after the commencement of carcinogenesis, paralleling histological evidence of very early dysplastic changes. Primary determinant was fluorescence intensity, although the wavelengths of the fluorescence emissions also changed over time. After 6-8 weeks, fluorescence intensity dramatically increased again, and was far greater than in controls. Using the one-end unpaired t-test, significant differences in fluorescence intensity between pathological and control cheeks were first identified at 4-6 weeks ( $p < 0.05$ ); another significant change occurred at 6-8 weeks ( $p < 0.03$ ). The fluorescence signature continued to change during the progressive development of squamous cell carcinoma. Fluorescence levels were greater 90 and 180 minutes than 30 minutes after ALA application. The progression of histological and fluorescence changes differed significantly between animals ( $p < 0.05$ ). Thus, laser-induced fluorescence after tissue exposure to ALA provides a novel, sensitive, non-invasive tool for the early detection and diagnosis of oral dysplasia and malignancy.

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### 40\*

#### MODELING THE MODIFICATION DEPTH OF PULSED LASER HEATED DENTAL ENAMEL

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**PURPOSE:** To predict the depth to which dental enamel heated by pulsed laser irradiation is sufficiently modified to reduce *in vitro* artificial caries-like lesion progression. **METHODS:** Bovine dental enamel was irradiated with 9.6  $\mu\text{m}$  laser light with 5 pulses of either 2  $\mu\text{s}$  or 100  $\mu\text{s}$  duration at incident fluences of 1 or 4 J/cm<sup>2</sup> respectively. Enamel samples were polished to remove material at approximately 1  $\mu\text{m}$  intervals. Between subsequent polishings, reflectance infrared spectroscopy was used to evaluate the carbonate band near 7  $\mu\text{m}$  as a function of depth. Tooth mineral consists of calcium phosphate with 3-6% carbonate as an inclusion. Previously, carbonate loss has been correlated to a reduction in caries-like lesion progression when dental enamel samples were subjected to a chemical model mimicking the oral environment. Scanning electron microscopy was performed on samples irradiated under the same conditions to determine the size of the apatite crystals as a function of depth. The experimental data was compared to a computer model that predicts maximum temperature rise as a function of depth due to pulsed laser heating to determine the temperature range at which enamel is modified. **RESULTS:** Temperatures in the range of 500 – 600° C remove almost 100% of the carbonate from the apatite structure of dental enamel. The depth at which this occurs is 3  $\mu\text{m} \pm 1 \mu\text{m}$  for 2  $\mu\text{s}$  pulses at 9.6  $\mu\text{m}$  and 8  $\mu\text{m} \pm 1 \mu\text{m}$  for 100  $\mu\text{s}$  pulses at 9.6  $\mu\text{m}$ . **CONCLUSIONS:** Our model is useful in predicting the depth to which enamel is heated and modified by pulsed laser irradiation. The depth of treatment may be critical to the efficiency of laser treatment for caries prevention *in vivo*. This study helps predict the optimal laser parameters needed to effectively modify dental enamel to prevent dental caries clinically. This work was supported by NIH/NIDR Grant DE09958.

### 41\*

#### SPOT SIZE AND BEAM PROFILE EFFECT OF LASER ABLATION ON HARD TISSUE

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The present work evaluates effects of different laser parameters on ablation efficiency and presents recommended laser beam parameters. Interaction of laser beam with hard tissue was analyzed for different spot sizes and beam profiles. It was shown that maximal crater depth depends on spot size and beam profile. A flat top beam provides deeper ablation than a Gaussian beam. For a wide range of laser beam parameters maximal crater depth is linearly dependent on spot size at constant energy fluence. Results of theoretical analysis are compared with experimental measurements. Experiments were conducted with the Er:YAG free-running laser on human teeth. Experimental results support theoretical analysis.

### 42\*

#### LASER ABRASIVE METHOD OF HARD TISSUE REMOVAL

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Both Er and CO<sub>2</sub> dental lasers are currently inferior to the high-speed turbine in terms of enamel removal rate. This limits the application of lasers for dental hard tissue treatment.

This paper describes the latest laser-abrasive method of dental hard tissue removal. The method is based upon the use of high-velocity hard particles. The air-abrasive method, which is well known, utilizes high-pressure air to accelerate 30-50 $\mu$  diameter sapphire particles. Similar to laser ablation, this method usually requires no anesthesia. However, there are performance limitations due to the very high divergence of the particles shot out of the handpiece nozzle.

The laser-abrasive method utilizes the energy of a laser pulse to accelerate particles. In this case, the dimensions of the particle beam on the tooth surface do not differ from the dimensions of the laser beam. Two methods of particle acceleration were demonstrated experimentally. The first one is based upon particle acceleration due to asymmetric laser ablation. Sapphire particles covered with a water film were accelerated by Er laser radiation ( $\lambda=2.94\mu$ ) up to a velocity of 150m/s. The same particles covered with carbon black were accelerated by Nd laser radiation ( $\lambda=1.06\mu$ ) up to a velocity of 30m/s. The second method is based on particle acceleration by Nd:YAG micro-explosion. At the enamel surface, 1-10 $\mu$  diameter sapphire particles created by Er laser radiation induced micro-explosion were accelerated up to a velocity of 50m/s. The use of enamel particles accelerated by micro-explosion increases the velocity of healthy enamel removal by a factor of 2-3. SEM investigations of the surface formed by fast particles in enamel and dentine show a microstructure of enamel prisms and dentine canals without residual damage.

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### CLINICAL EVALUATION OF A FREE-RUNNING PULSED ND:YAG LASER ON TWO PERIODONTOPATHOGENS: COMBINED ANALYSIS FROM TWO CENTERS

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The purpose of this study was to observe the effect of a pulsed Nd:YAG laser on two anaerobic periodontopathic bacteria. A total of 22 patients at the University of Texas Health Science Center at San Antonio (UTHSCSA) and the University of Louisville (UL) were treated nonsurgically for periodontal disease in split-mouth, randomized, double-blind studies. The oral cavity was divided into four quadrants: (1) standard mechanical scaling and root planing, (2) laser treatment (PulseMaster Nd:YAG Laser, American Dental Technologies, Southfield, MI) of 80 mJ at 20 pulses per second as an adjunct to standard mechanical treatment, (3) control, and (4) at UTHSCSA the remaining quadrant received laser treatment and at UL randomized laser or standard treatment. Short-cloned DNA probe analysis of *Porphyromonas gingivalis* and *Prevotella intermedia* was performed at baseline, 1 week, 1 month, and 3 months.

Microbiological Culture - Percent Reduction from Baseline

	1 Week	1 Month	3 Months
<i>P. gingivalis</i>			
Laser Treatment	98%	97%	96%
Standard Treatment	98%	97%	94%
Control	45%	56%	62%
<i>P. intermedia</i>			
Laser Treatment	93%	87%	87%
Standard Treatment	96%	87%	83%
Control	18%	57%	31%

The laser treatment as an adjunct to standard mechanical treatment was effective in reducing bacteria and inhibiting bacterial recolonization and was comparable to the standard treatment of scaling and root planing alone.

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### Bactericidal effect of diode lasers in root canal dentine

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#### Abstract

The microbial colonisation of root canal dentine can lead to failures in conventional endodontic treatment if only an inadequate bacterial reduction is achieved through canal treatment and chemical disinfection. The goal of this study was thus to investigate the antibacterial effect of a diode laser in deep root canal dentine. 100  $\mu$ m, 300  $\mu$ m and 500  $\mu$ m bovine dentine slices obtained by longitudinal sections were sterilised and contaminated on one side with an *Enterococcus faecalis* suspension. Laser radiation was performed on the opposite side with a diode laser at a setting of 3 watts in continuous mode (cw). Radiation was performed using a 400  $\mu$ m fibre at an angle of approx. 5 degrees to the surface over a period of 30 s. The germs were then detached through vibration and cultured on agar plates. The colony count reflected the antibacterial effect of laser radiation as a function of the layer thickness.

A mean germ reduction of 74 % was achieved with a 500  $\mu$ m thick slice.

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### Composite Restauration of Er:YAG Laser Prepared Cavities: A Clinical Study

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The Er:YAG laser is preferred for application on dental hard tissues because of its capability to avoid thermal damage to the tooth's hard substance or pulp. Various *in vitro* studies and animal experiments have been published describing basics in laser treatment and restoration.

The present study intended to compare the composite restorations after treatment either with the conventional dental drill and acid etching or with the Er:YAG laser and laser-conditioning of dental tissue surface under clinical conditions. The study population consisted of 118 cavities from 26 patients. Filling procedure was documented through slides and control occurred three (3), six (6) and twelve (12) months after treatment.

Even cavities with small amount of enamel at their margins were successfully restored without acid etching. Same aesthetic and functional results were observed for restorations after conventional or laser treatment. Even after artificial opening of coronal pulp and sterilization with Er:YAG laser without anesthesia vitality loss did not occur.

The present study provides evidence that aesthetic and functional composite restorations after cavity preparation and caries therapy can be achieved by Er:YAG laser treatment. Teeth surfaces with few prismatic structures can be treated and restored with composites. Phosphoric acid etching can be avoided.